

“Aviation Daydreaming”
NASA Administrator Daniel S. Goldin
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Thank you for that generous introduction.

Before I begin, I want to salute everyone at AIAA and SAE who worked so hard to make this conference happen.

It is good to see so many of our partners and friends from around the world here today. Today, I will address everyone, but much of what I am going to say is meant for the American aviation community – Team America – that includes industry, academia and government stakeholders. We have many challenges before us.

We at NASA have a unique relationship with the rest of Team America. We develop and validate long-term, high-risk, high-return innovative technologies. Then we hand it off to industry, and they develop, build, and operate the products.

Industry “puts the rubber on the road,” or more appropriately, “lifts the wheels off the runway.”

You know, in just a few years, we will celebrate the 100th anniversary of the Wright Brothers’ historic flight.

What will we celebrate when we reach that milestone?

More importantly, when people in 2103 celebrate the 200th anniversary of human flight, what will they say about our efforts in the coming years?

Will it be, “The aviation sector really improved the quality of people’s lives in the 21st century,” or will it be “The aviation sector really blew it in the 21st century”?

Guess which one I want to hear. The only way it will happen is for us to dare to dream.

And then roll up our sleeves and work together to make those dreams reality.

We already have a terrific team in government, industry, and academia that is working hard to make that happen.

These great people are being pushed to their limits because there is so much demand for air travel. But I don’t think anyone could have predicted the

unprecedented years of economic prosperity that has fueled our rush to the nation's airports.

The issue is that the necessary technologies are not on the shelf right now.

And federal spending constraints have exacerbated the situation by limiting funding for developing cutting edge technologies.

Clearly, there are some daunting challenges in our future, including safety, capacity, noise, emissions, performance and cost. It all adds up to improving the quality of life. But our combined intelligence and innovation are far greater than the challenges we face.

We have come a long way since the DC-3. This is a mature industry that has contributed much to the overall quality of life. Aviation has made the world much smaller. Today, we can reach any point on Earth within 24 hours.

But there has been a price as well. With so much capacity to travel, the world has become a very cluttered place. America's hub and spoke system carried 680 million passengers this year. A number that will exceed 1 billion early next decade and reach 1.5 billion by 2020.

We are crowding our airways, our airports and our world. We all want to travel to any place, at any time, from any where. But we demand it be done safely, conveniently and economically without adversely affecting the environment or our neighborhood.

These are clearly not mutually exclusive factors.

One must take a rational approach not only to understand the complex interactions among these factors but also to assure the goals we are trying to achieve are properly balanced.

Right now, for a doorstep to destination trip under 500 miles, the average speed is just 80 miles an hour—not much faster than the highway system on those rare occasions it operates at peak speed.

I encounter this problem all the time during my frequent trips throughout the Northeast corridor.

We absolutely must move that average speed much closer to aircraft cruising speed.

Our challenge is to expand the capacity of our major airports and open access to the over 5000 smaller airports that can serve small cities and communities

across the country. The goal: safer, cheaper, more accessible air transportation for all. Again, it gets to quality of life.

If we fail to meet the challenge, the alternatives are not good. Quality of life and economic prosperity will suffer.

Another risk faced by air travel is the Information Revolution. Business travel blossomed in the 1970's as availability grew and prices fell. People could travel affordably and conveniently.

However, as we enter the next millennium we will be able to "be" anywhere we want without having to physically be there. We are on the verge of ultra-high speed communication and wide-spread networks -- the "Internet II" -- that will link us through "virtual presence". First it will be wall-sized, high resolution displays with life-like 2-Dimensional imagery. But soon to follow are fully 3-D immersive environments. When all the senses say you are there, the geographic reality is not relevant.

Business travel, the main stay of modern air travel, may go the way of the vacuum tube, if we do not rise to the challenge. That means being on an airplane can't be much different than being in an office. When you board the plane, you must be able to take your entire office environment with you and be able to communicate on a global basis.

The alternative is simple. We need to team up and meet the challenges head-on. That's what America is all about.

The future of air travel will be both evolutionary and revolutionary. Our medium and long-haul aircraft are very good. Still, we can make them somewhat lighter, more fuel efficient, more aerodynamic and less expensive. But we are not talking factors of 10 and in most cases not even factors of 2.

The revolution will likely come in smaller aircraft—the more individualized craft, transporting 4 or 10 or 40, not hundreds—and in super- and hyper-sonic speed for long haul planes.

As commercial air traffic increases, we will see more accidents, unless we revolutionize the entire air transportation system. But the public doesn't care about accident rates per mile per passenger. That's just gobbledygook to them.

Actual numbers of fatalities—that's something they personalize, thinking "wow, that could have been me."

We need to do everything we can to make the public feel safe, whether they fly or simply live near airports.

Right now, about 85% of all fatal accidents fit into one of four categories: limited visibility, weather, loss of control of the aircraft, and on-board system failure.

I'd like to take a minute to look at how we are responding to these issues.

NASA is committed to working with the FAA and the U.S. Aviation industry to cut the fatal accident rate 80% by the end of the next decade and then cut it in half again in the decade after that.

One of NASA's most exciting projects to enhance visibility is in what we call artificial vision—the development of advanced sensors, digital terrain databases, accurate geo-positioning, and digital processing to provide a perfectly clear 3-D picture of terrain, obstacles, runway, and traffic.

This goes beyond simple visual imaging through clouds and weather. It enhances the elements you need to see and suppresses the ones you don't. It will ensure a reliable and easy system for threat avoidance, regardless of whether the threat is a mountainside or a recently constructed transmission tower. And it will provide clear warning advice and guidance to the pilot.

Such a system could enable safe and reliable day-night-all weather in-flight and on-ground operations. And not just for the most experienced pilots.

Today, anyone with cable television can get a better picture of the nation's weather than a pilot in flight. We've established partnerships with four separate teams to show how to bring an "Aviation Weather Channel" into the cockpit.

I don't mean that pilots will only view ground-based and aircraft-based radar images of weather systems. They will have the macro view as well as a real-time, micro view of all weather in the vicinity of the aircraft and along the flight path.

I'm talking about a 3-D depiction of complex weather patterns that clearly shows the locations of hail shafts and windshear, lightning and storm cells. It'll give us a pathway—the highway in the sky—for safely navigating through nearly any weather condition.

A few years back NASA, the FAA and the aviation industry made a concerted attack on wind shear. In the 1980's, major wind shear accidents were occurring at a rate of one every two years. Through training, improved ground systems and NASA-developed forward-looking radar technology, the wind shear problem has been cut about 80%.

We're also working with the FAA and the industry to better understand and model the turbulence hazard, then develop and evaluate prediction, detection, and avoidance technologies, including radar.

And recent NASA flight tests indicated that lidar could detect clear air turbulent conditions about 10 seconds ahead of the aircraft. We're working to stretch that timeframe into minutes.

Our goal is to eliminate turbulence as an aviation hazard within the next five years.

An issue closely linked to safety is capacity.

Right now, there is simply too much demand on a system ill-equipped to handle it. In 1996, air traffic delays in the U.S. averaged 8,000 hours each day at a daily cost of \$10M. As air traffic increases in the current system, those numbers will skyrocket, and the quality of life for both the flying and non-flying publics will deteriorate.

And the short-haul system needs improvement too. It costs people more to fly the 150 miles from Washington, DC to Williamsburg, VA than it costs them to fly to San Francisco.

About 1/20th the distance for twice the price...doesn't motivate people to use air transportation for short-haul trips, does it?

And there are only one or two flights a day to Williamsburg. But travelers to San Francisco can almost pick the hour they want to leave.

Playing the blame game won't solve the problem. The reality is that we are pushing against the limits of our existing technology.

That's why NASA is committed to providing technologies that will enable tripling the throughput of the aviation system within the next decade or two. And with our partners in the FAA, industry, and academia, we will do it, and under conditions that are far safer than today.

The total suite of tools we are working on now should improve throughput in the terminal area and in the routing process.

One tool is the Final Approach Spacing Tool (FAST), which has been tested at the Dallas-Fort Worth airport. The result? A 13-15% improvement in numbers of takeoffs and landings—the equivalent of adding a new runway.

We are also working on a wake vortex sensing and prediction system that allows controllers to more accurately space aircraft on approach. One recent study suggests that reducing the average aircraft separation by one mile could increase total capacity by 30%.

To triple capacity, we also need new aircraft classes that will off-load the main runways of our nation's most congested airports and decrease costs and increase accessibility in the short-haul system. This will include Runway Independent Aircraft capable of take-off and landing on whatever ground is available—independent of size and direction.

Beyond safety and capacity, noise is another major challenge.

In 1998, 350 airports throughout the world had local noise restrictions in place. If we can't design engines and airframes that are much quieter than today's, we will soon be unable to sell American planes in certain markets.

However, we're already well on our way to a 10 dB reduction of noise within the next 10 years.

And we can do even better. It will take the best and brightest of Team America to make it happen though.

Since we're here in California, I'll take this opportunity to discuss airplane emissions and the resulting smog.

If this isn't a quality of life issue, I don't know what is. We all know that 70 Million people currently live in areas that exceed the federal standards for NOx and ozone. These gases have known linkages to respiratory diseases which particularly attack the young and the aged.

Right now, airports across the nation are being restricted from growing, either because of the smog-producing gases or the noise from their airplanes.

Soon, you may not be allowed to land in certain cities because of the emissions or the noise of the airplane you are flying in.

We need a clear investment plan for developing rational solutions to noise and emissions problems. We do not need arbitrary regulations put in place before technologies are developed, verified and available.

Today NASA researchers working with industry have a combustor concept that might eliminate 70% of the NOx emissions. This may be in the laboratory today, but we hope to see it in the engines of the future.

This is not just about eliminating the barriers to growth, it is about competition too. When we solve the safety and environmental problems, we will increase the value and competitiveness of U.S. aircraft.

At the same time, Team America will work on the revolution of the entire air transportation system.

What good will it do us to have incredibly smart, safe and reliable aircraft if the entire air transportation system doesn't support them?

That's right...the entire system. All 5000 plus airports throughout the nation.

Everything is inter-related here—the evolutionary advances will set the stage for a revolution in aviation.

And what are the revolutionary areas?

I'm talking about vehicles and vehicle concepts spanning the entire range of systems, speed, capacity, and capability, that creates a fully integrated, full-service transportation system.

That's a revolution we need to make happen.

Beyond aircraft that carry people and cargo, we are developing aircraft for non-conventional applications, like disaster relief coordination.

Such aircraft provide a low-cost infrastructure for rural areas or areas where communications are temporarily destroyed—like a hurricane ravaged area.

It would be like AWACS for everyone.

Fully autonomous FAA-certified flight durations up to 6 months are needed for this application. The Helios, currently flying at NASA's Dryden Flight Research Center, is a prototype for this new aircraft. It will fly at up to 80,000 feet, making it independent of weather and other potential threats.

An aircraft like the Helios could be deployed to a disaster area to provide cellular telephone relay for relief workers and high-resolution imagery for rescue targeting. The aircraft could have been used over North Carolina to target people for rescue or for food and supplies if rescue is delayed. Longer-term environmental monitoring and research, border patrol, and drug surveillance are additional roles for this aircraft.

For years, there seemed to be no outlet for radical new ideas. So we started a program to develop revolutionary aircraft for new applications—REVCON. If you have ideas for revolutionary aircraft, submit them to NASA's REVCON.

Right now, we have REVCON projects that take us far into the future.

For example, the Blended Wing Craft, which we are working on with our industry partner, integrates engine and airplane designs to create a low noise, low emissions, more volumetrically efficient operating system.

And we are working on technologies to produce a substantially improved supersonic engine. One approach, the Pulse Detonation Engine, gains higher reliability, lower cost, and a longer life by eliminating complex rotating turbo-machinery components.

Beyond revolutionary vehicles and vehicle technologies, we are working to revolutionize the entire air transportation system.

One approach NASA is exploring involves the infrastructure and aircraft breakthroughs that will allow America to realize the full potential of General Aviation.

We hope this approach will free people and products from gridlock and hublock delays, by creating faster, lower cost, and safer access to more communities.

A preliminary goal for this technology is to cut inter-city travel time by more than half, while maintaining affordable costs.

Think Learjet performance for travelers at a fraction of today's prices.

Think precision approaches to virtually every runway end and helipad in America.

Think economic development enabled by accessibility for any community regardless of population or existing industrial base.

In a few decades - with aggressive, visionary, and bold investments – we could put together all the technical achievements in safety, noise, emissions, capacity, cost, and revolutionary designs. We could produce a seamless transportation system with tremendous “doorstep to destination” speeds.

What might such a system look like? Let me take you on a little journey.

A husband and wife and their two children are headed home to Pigeon Forge, Tennessee—in the heart of the Smokey Mountains—after taking their oldest daughter to Chico, California, where she is starting college.

The wife is a military aircraft design engineer for a West Coast firm. Next-generation fully immersive collaborative computer environment technologies, like NASA's Intelligent Synthesis Environment (ISE), let her work with the design team even though they live thousands of miles apart.

This family came into the San Francisco Airport from Chico on a new Runway Independent Aircraft, an advanced version of the V22 Tiltrotor. They were a little disappointed, because they really wanted to try out the new STOVL aircraft just

completing certification. It has morphing, mission-adaptive wings, derived from technologies NASA began working on back in 1999.

At SFO, they board a modern, quiet, low emission transport aircraft that has just completed a self-check of its structures and flight systems and certified itself “ready to fly” by using its integrated vehicle health management system.

As they push away from the gate, the fog is thick and visibility is low, but safety is not affected and the flight will not be delayed. The crew is using the advanced taxiway and runway navigation and visualization tools developed by NASA and the FAA. A computer that efficiently manages planes on the ground and in the air clears the pilot for takeoff.

Enroute to Chicago O’Hare, the family uses the integrated communication system to confirm their rental jet. They are looking forward to the one-hour shuttle jet ride to Pigeon Forge because they can stop in Kentucky to see relatives if they want. They have that luxury, because their door-step-to-destination time has been cut by a factor of four.

In Chicago, they get off the plane . . . and follow the signs to the Hertz Rent-A-Jet counter.

The family confidently boards their rental jet . . . the days when General Aviation airplanes were a factor of 10 less safe than scheduled airplanes have long passed.

In fact, they pre-flew this trip during the flight to Chicago, using their laptop. The simulation included real-time updates, optimized route planning, and it assures the family’s safety when they make the actual flight.

The trip is surprisingly inexpensive.

As a matter of fact, thanks to the advances we spoke about earlier, the price of all airplanes has come down dramatically.

Both the husband and wife can fly . . . because years ago, their employers saw the advantage of personal air transportation to business . . . and knew that with personal air travel they could accomplish in one day what used to take 3 or 4 days back in 1999.

Their middle child is 15. Next year he will enroll in “Flyer’s Ed” at school.

The rental jet is equipped with intelligent avionics . . . and the family cannot even fathom that there was a time when people didn't have real-time, on-board assessment of aircraft health, local atmospheric conditions, artificial vision, and air traffic. They pity pilots in the “aviation Middle-Ages” – the 1990’s.

In 2020, controlled flight into terrain and weather hazards are no longer major causes of accidents, and general aviation will never again take a back seat in safety.

Unlike the old days in 1999, the pilot's route is nearly a straight line because of the Free Flight capabilities developed by NASA and the FAA. The "Smart Airport" system provides excellent separation and sequencing of aircraft, even without control towers or radar, and an "Airborne Internet" provides real-time weather, traffic, and landing facility data. With these new systems pilots avoid constant flight path re-vectoring— saving fuel and time, while increasing safety and reliability.

The plane slips quietly and cleanly through the air. It is much quieter outside the plane and inside the plane for passenger comfort. Engines are quieter, and smart airframe and interior wall structures actively cancel out most of the noise that would otherwise be heard and felt in the cabin, eliminating travel-induced fatigue.

The plane's 3-D, multi-media communications environment allows them to virtually visit their Kentucky relatives. During the conversation, they smell the turkey cooking and are invited to stop for dinner. They leave their rental jet at a small unattended "Smart Airport" in eastern Kentucky where their relatives are waiting to pick them up.

After dinner with their relatives, the family takes a cab to the airport. And after a short plane ride to Pigeon Forge, they are home in time for bed.

A bold vision? Sure.

Can we get there? Absolutely.

We just have to work together with the same goal in mind—air flight anywhere, anytime, by anyone. With increased safety and increased reliability, even as capacity skyrockets.

That will enhance people's quality of life and it will energize the aviation industry like nothing ever has.

And what lies ahead? What the nation needs is a radical new paradigm for transportation management. From a systems perspective, any trip we make involves more than one mode of transportation. Therefore, we must integrate communications and transportation.

We need a system that recognizes and accounts for tremendous information management. Imagine planning your entire route and knowing at any point along

the way, this system is ensuring that your connection at the next node will be seamless – no delays.

The revolutionary pathway to future air travel will require embedding levels of intelligence throughout the entire air transportation system. This will enable systems that can adapt to unanticipated problems, recognize and mitigate failure modes and rapidly evolve to counter changing conditions and environments.

We are moving into a technology domain called “soft computing”. How many of you are familiar with this term? This is the wave of the future.

This technology is how we will deal with uncertainty and risk in both the design and operational environment. This will take us from the deterministic world into the real world of complex, dynamic processes for modeling, designing and operating our engineering systems.

The most commonly known example is neural networks, which mimic the function of the brain. Neural networks assimilate vast amounts of data and extract information – trends, patterns, solutions--the kind of thing we do when we learn and think.

Today we can build systems with hundreds to thousands of neural connections. In the future they will have millions of connections in a package the size of a sugar cube.

NASA applied neural networks to the flight controls of an F-15 aircraft. The traditional flight control software system required one million lines of code. We reduced it to about ten thousand.

We demonstrated improved performance. We introduced software faults, and the system identified the problem and self-corrected in seconds.

We simulated loss of aileron roll control, and the system adapted and returned aircraft control authority.

Embedding intelligence into future systems will free us from this dreaded “curse of software”. The majority of the problems that occur in NASA spacecraft are software related. The software has become so complicated that absolute validation – absolutely no errors – is impossible to achieve. And a single error on any line of code can be disastrous. But soft computing is error tolerant and self-correcting.

It will enable the cockpit and the space systems of the future. Imagine this. The cockpit will not be an array of dials, gages or even multi-functional displays. It will be a fully immersive environment where pilots have a 3-dimensional view of the

world around them and of the aircraft they are flying. They will have a fully transparent view of all systems from any vantage point.

This “virtual” cockpit will hold more than just a crew. Anyone and everyone the pilot needs will have the same view of the aircraft. A complete engineering staff and operations team will be there with the pilot if needed. Not in person, but there nonetheless. Couple this with integrated health management systems and intelligent monitoring, intelligent diagnostic systems, and multi-layered pathways for true adaptive failure recovery, and we will achieve unprecedented safety and operational reliability.

We will monitor every parameter, every second of every flight every day of the year.

We’ll be able to answer questions like:

Are approach patterns at certain airports becoming less stable and consistent?

Is a certain noise abatement procedure diminishing safety margins?

Is a certain engine under-performing and heading for early failure?

In short, we’ll begin to have intelligence in our systems.

We will move from data . . . to information . . . to knowledge . . . to intelligence.

And the ultimate future of aviation will extend beyond Earth’s atmosphere. It is NASA’s job to understand and remove the technical barriers to that.

And 100 years from now, when space is open to the public, you will be the ones who take them there.

When? I don’t know. But if we don’t begin dreaming, we will never get there. We won’t even believe that we can.

One way we’re trying to enable easier access to space is through our X-vehicle program, which innovates and integrates aeronautical and space technologies.

Advanced propulsion system technology that NASA is developing today will enable future aircraft to cruise at high altitudes and at either supersonic or hypersonic speeds.

An initial demonstration of one of these technologies is planned for next year with the first flight test of the X-43, Hyper-X, flight test vehicle. The Hyper-X is an airframe –integrated, supersonic combustion ramjet (SCRAMJET) powered vehicle. Its propulsion system contains no rotating machinery, but rather uses

the aircraft's shape to provide compression of the flow entering the engine, where the combustion process occurs in a supersonic stream. And the shape of the vehicle's aft end acts as a nozzle for thrust.

And this is just one of many vehicles to come. Each will be a testbed for different vehicles technologies and speed regimes.

The future will bring us many technological surprises, often coming from unexpected places such as biology. This is the last great bastion of science to be brought into the realm of technology.

We have made great strides in understanding the underlying processes that have evolved over the past billion or so years and now this knowledge is about to revolutionize all areas of engineering. It is somewhat ironic to be saying this about aviation since the original inspiration for flight came from biology.

From biology will come concepts for sensors, brain-like computers and distributed nervous systems far beyond even the neural networks we are developing. Biology based systems can be orders of magnitude more power efficient, compact and sensitive than conventional silicon systems.

The related field of nano-technology will deliver material systems made from the bottom up – atom by atom – that will approach theoretical limits. Perhaps 100 times stronger than steel and 10 times stronger than the best graphite fiber. One such concept is carbon nano-tubes—tiny nano-scale fibers that self-assemble from carbon-based precursors under the right conditions.

We may literally grow aircraft skins in the future. Not just for structure, but multi-layered for environmental protection and with imbedded sensor grids. When they are damaged they may even self-heal, just like we do if we are injured.

What an amazing future we have before us!

NASA will not be able to do this all by ourselves, nor do we have a monopoly on innovative technology.

We need to develop even stronger partnerships:

- with the FAA
- with the DOD
- with the Large Airframe and Engine Companies as they evolve aircraft designs
- with small & start-up companies for more revolutionary concepts
- with academia.

Partnerships between traditional aerospace disciplines and information technologies and between the aeronautics and space transportation disciplines.

As partners, we need to dare to dream.

And as we dream this morning, let us remember the words of T.E. Lawrence:

“Those who dream by night in the dusty recesses of their minds wake in the day to find that it was vanity. But the dreamers of the day are dangerous men, for they may act on their dreams with open eyes, to make it possible.”

So become daydreamers.

And together we will build an air transportation system that will still be improving the quality of life 100 years from now.

Thank you.